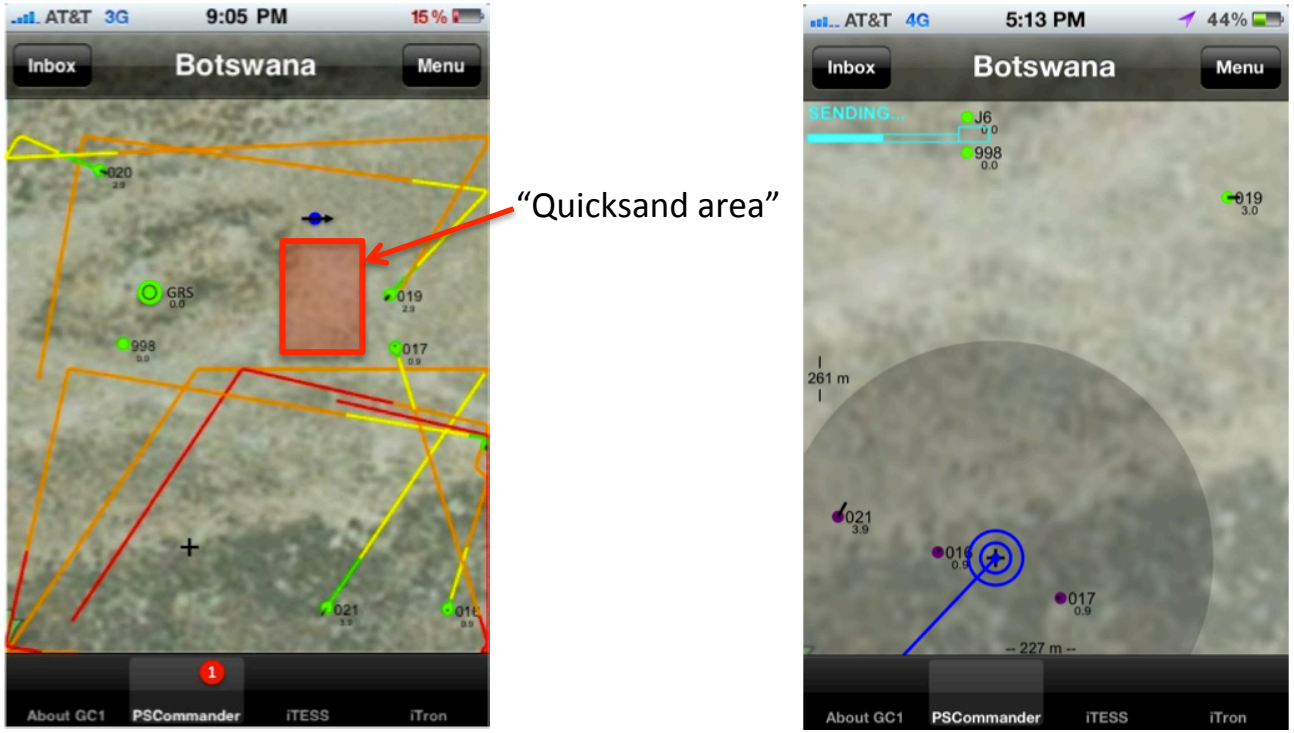
Scalable Geocast Based MANETs



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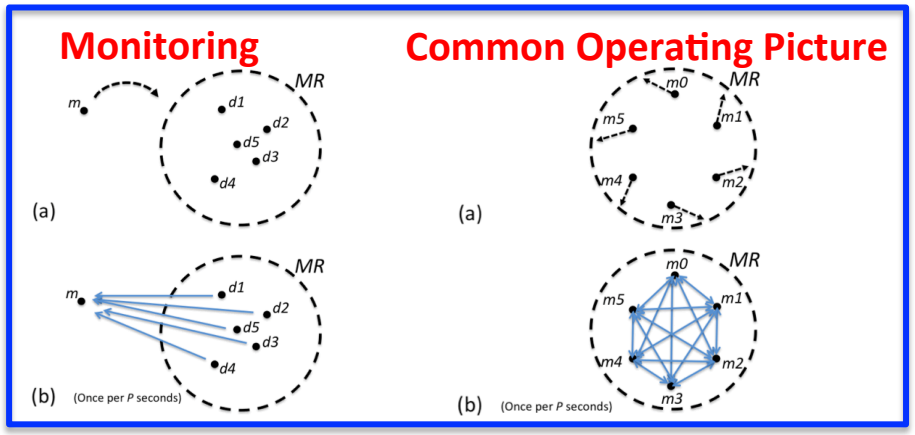
Intro and Motivation

- **Goal:** bring timely information to every operator in the field, anytime/anywhere
- **Observation 1:** traditional approaches to field data networking in MANETs is problematic
  - Node mobility + terrain make routing topology dynamic and fragile, maint. overhead burdensome
  - Traditional unicast-based information distribution patterns do not scale well with (geographic) node density in MANETs

Intro and Motivation

- **Observation 2:** Worst scalability problems stem from need to send *same* information to all in an area
  - ***Common operating picture problem***
    - Real time location and telemetry tracking of all to all
    - Mutual distribution of annotations and collaboration information



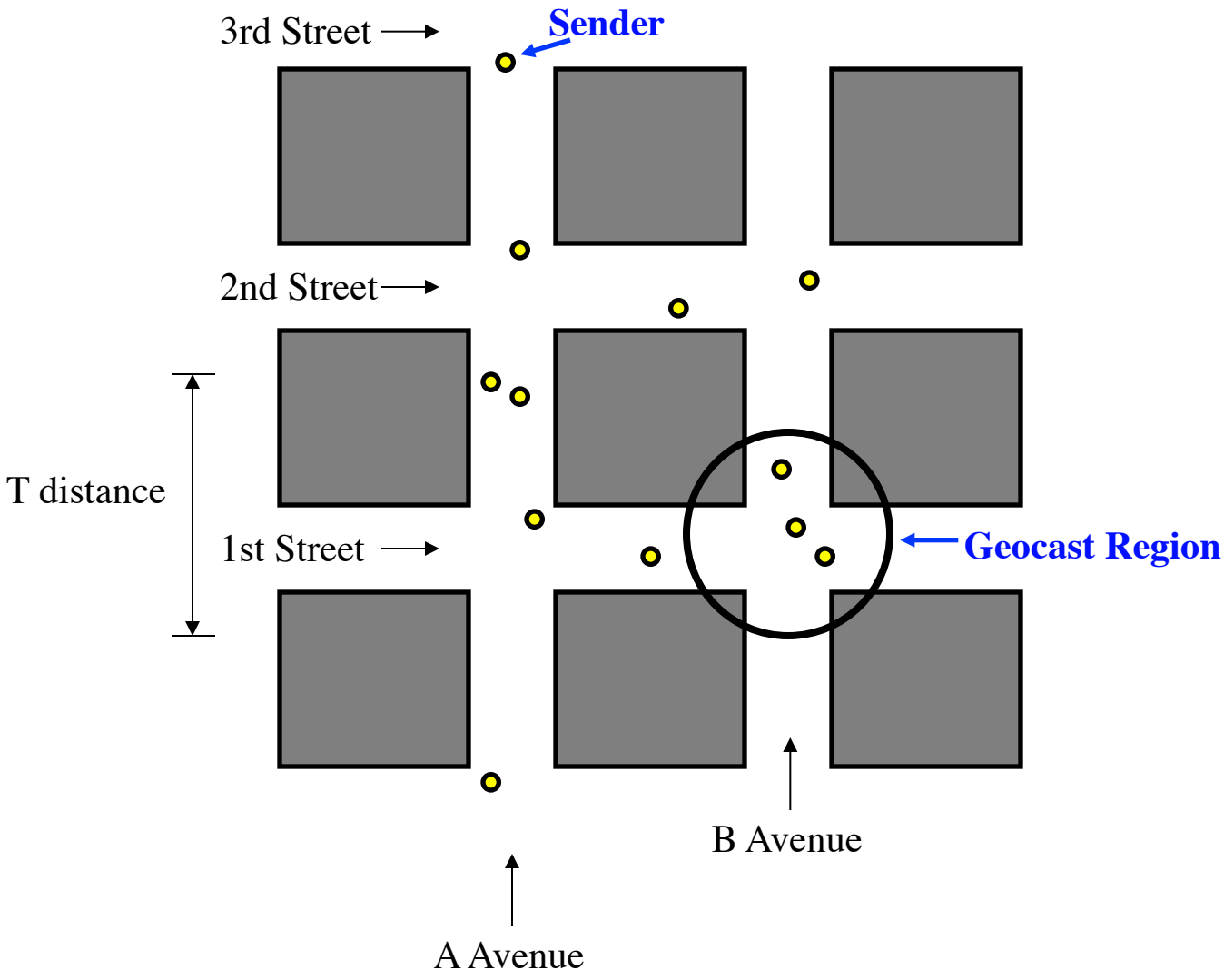
  - ***Field file transfer***
    - Transfer of imagery, maps, data to all operators in area

Solution Key Ideas

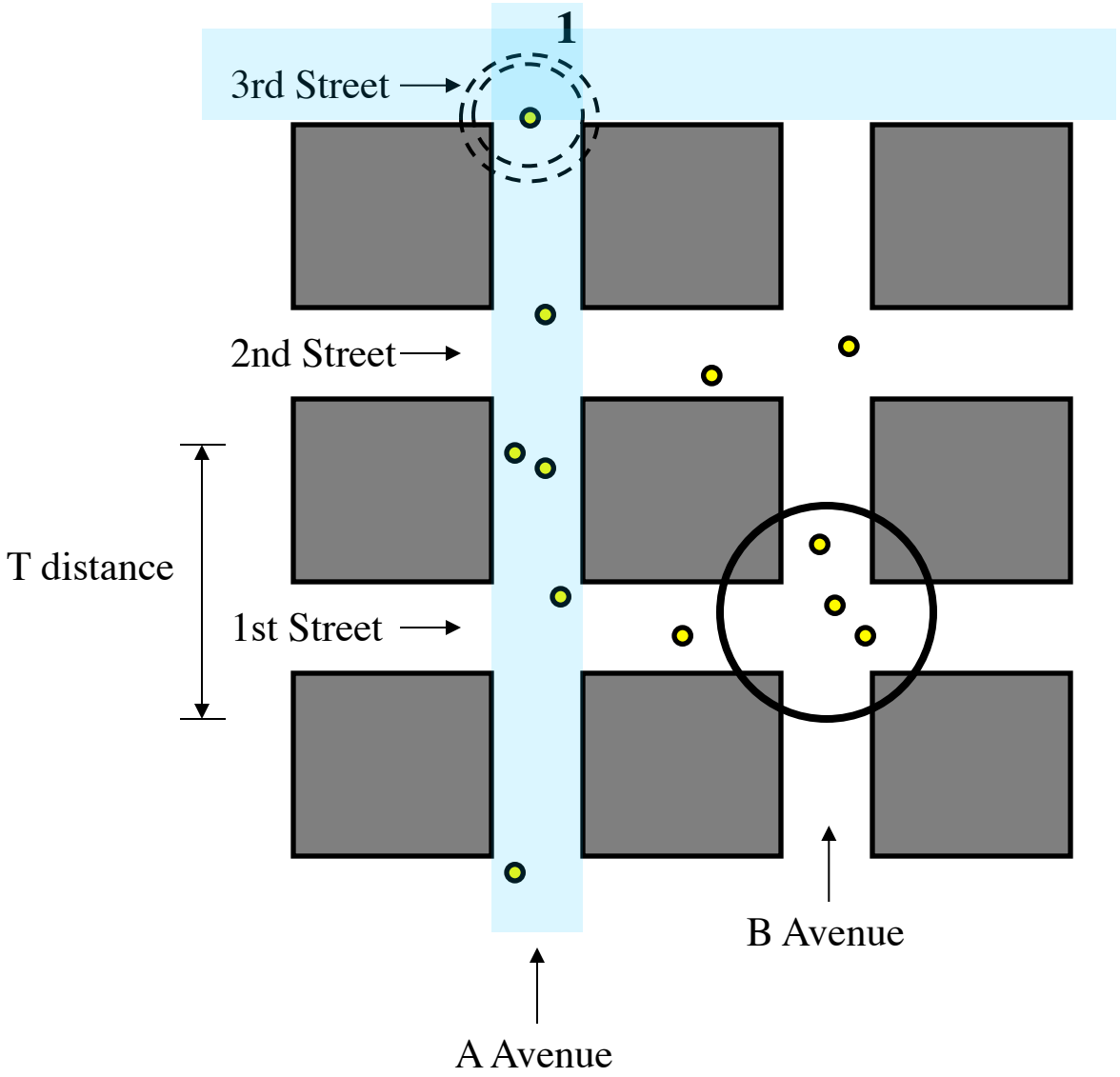
- **Key Idea 1:** Build field network on top of a *Scalable Ad Hoc Geocast Protocol (SAGP)* [1]
  - Not built on IP, but can interoperate with it
  - More scalable than flooding (lg *n* vs *n*)
  - *Side benefit*: geocast can discover a fresh unicast route for efficient 1-1 replies (reverse path forwarding)
- **Key Idea 2:** Exploit efficient 1-to-many geographic multicast for efficient applications
  - *Field Common Operating Picture (FCOP) Protocol* [2]
  - *Geocast File Transfer (GFT) Protocol* [3]

1. *IEEE Trans. Mobile Computing*, 2011 **2. MILCOM 2012** **3. MILCOM 2013**

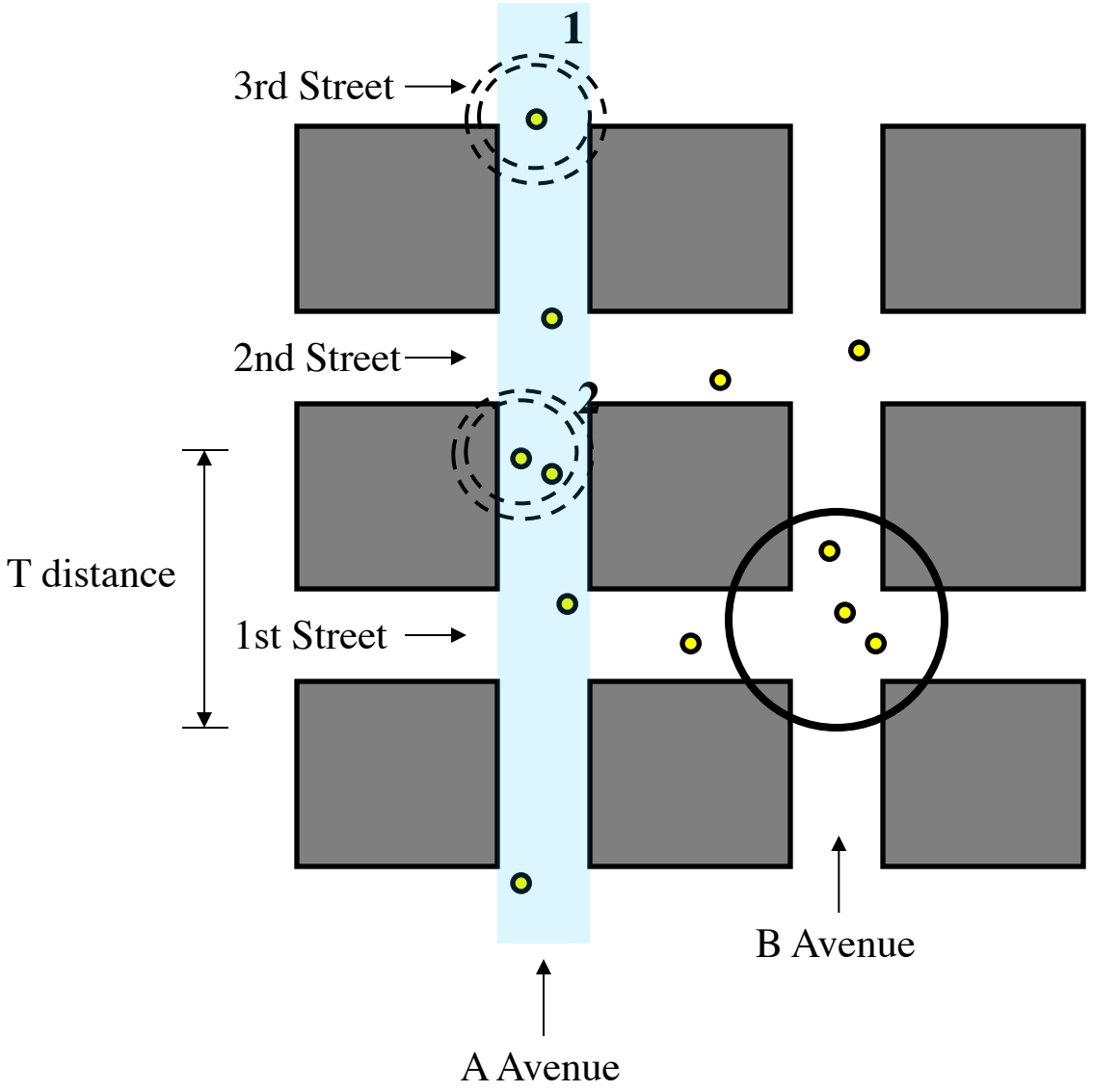
SAGP Animation



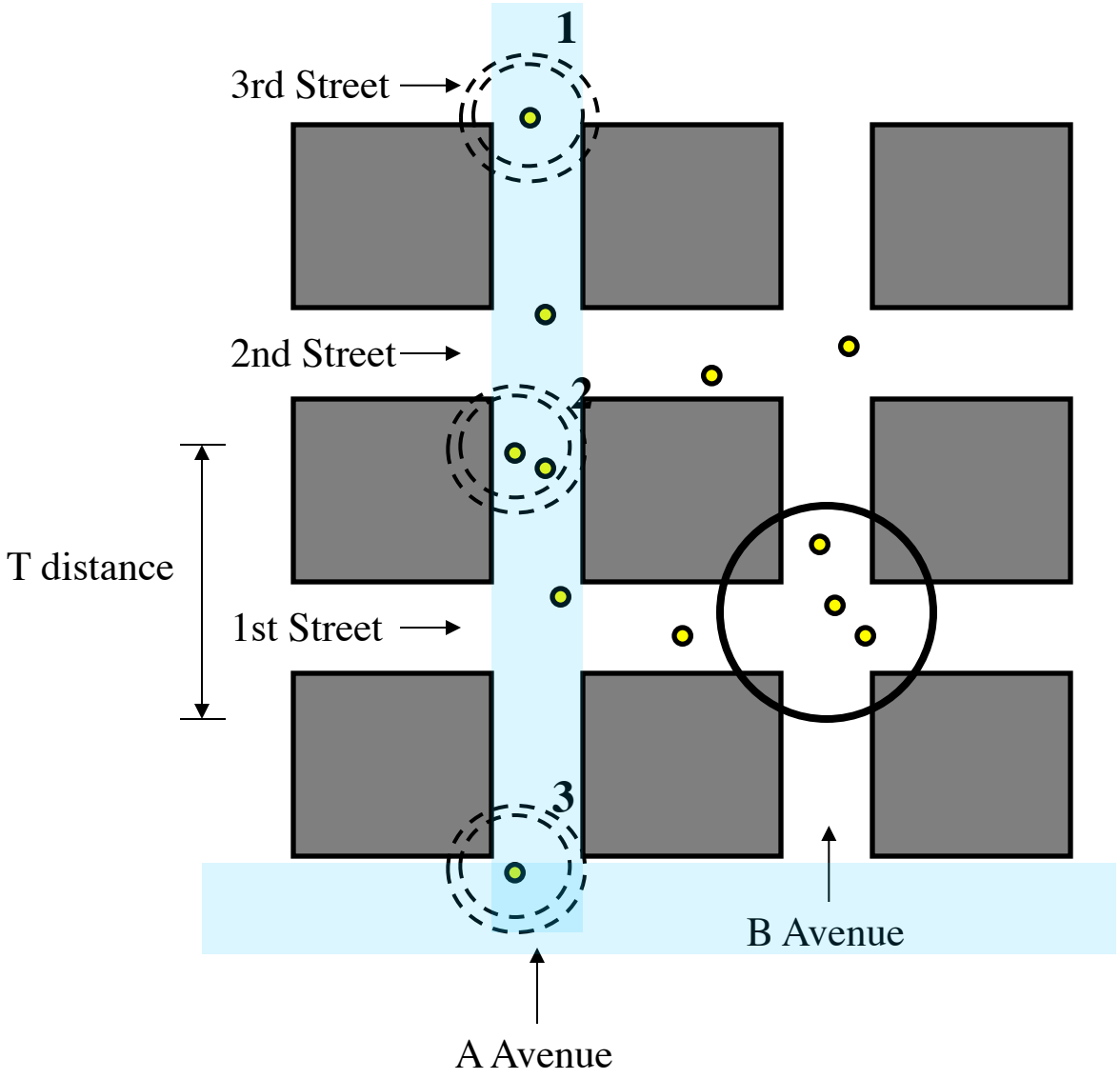
SAGP Animation



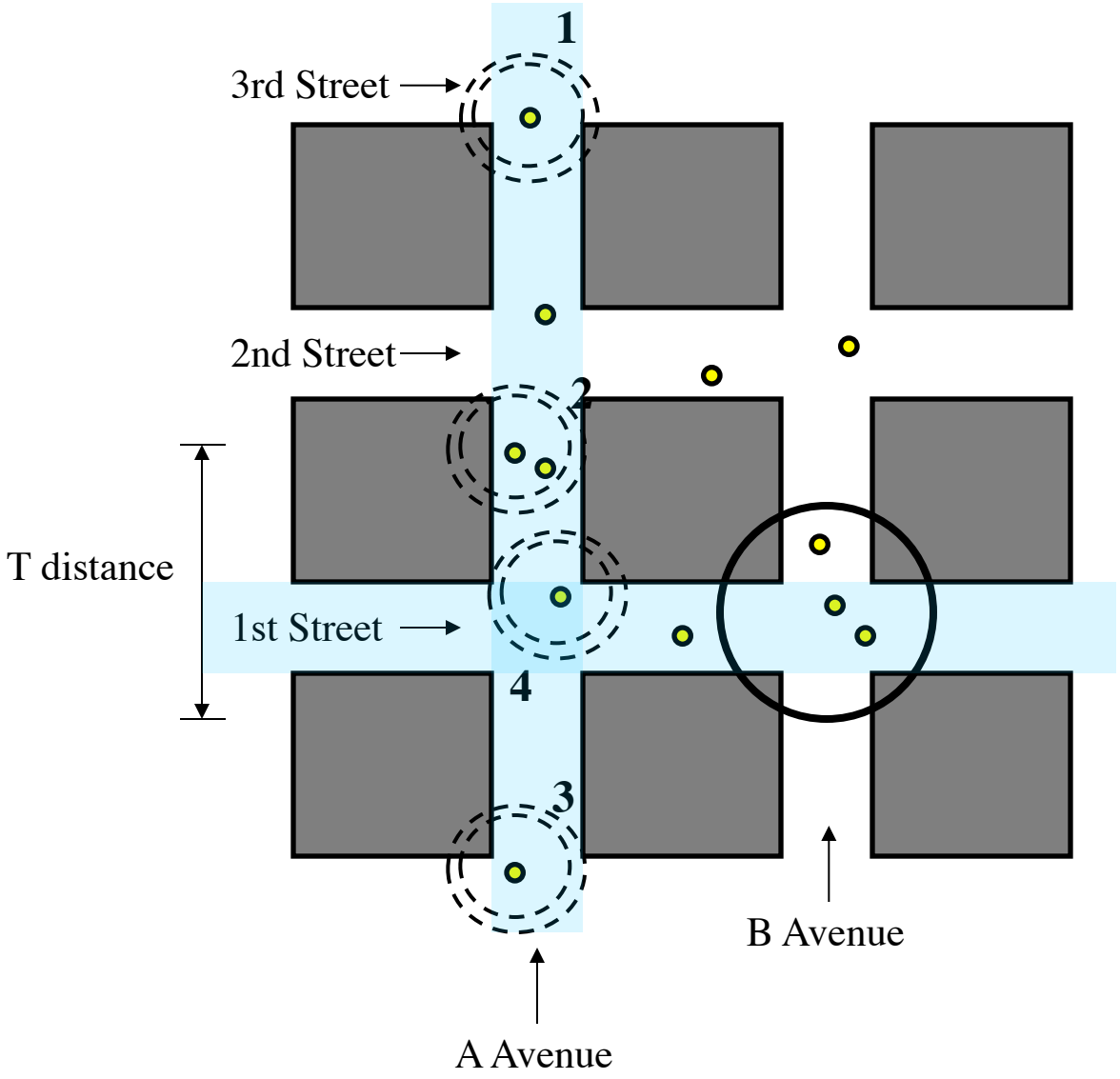
SAGP Animation



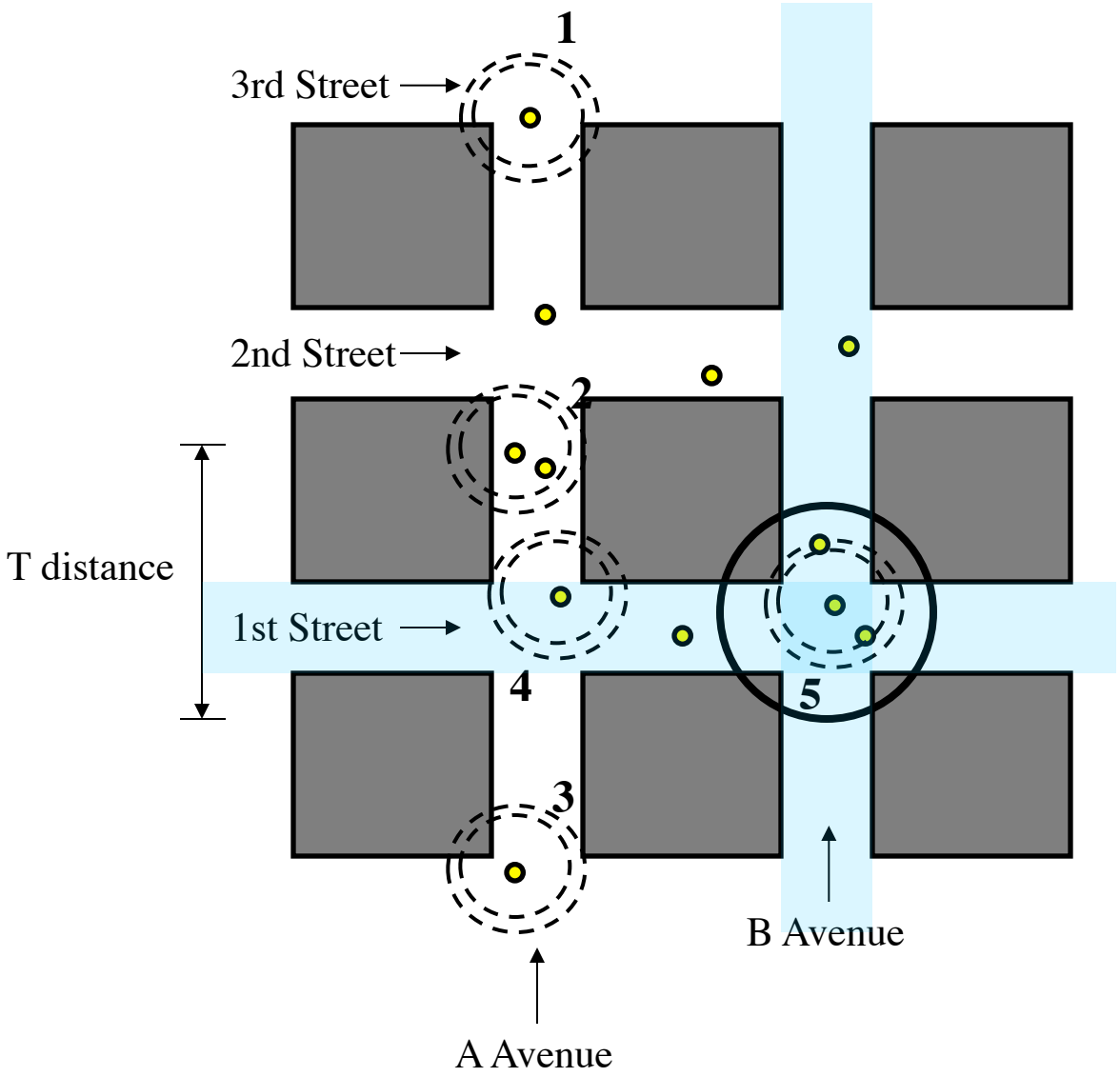
SAGP Animation



SAGP Animation

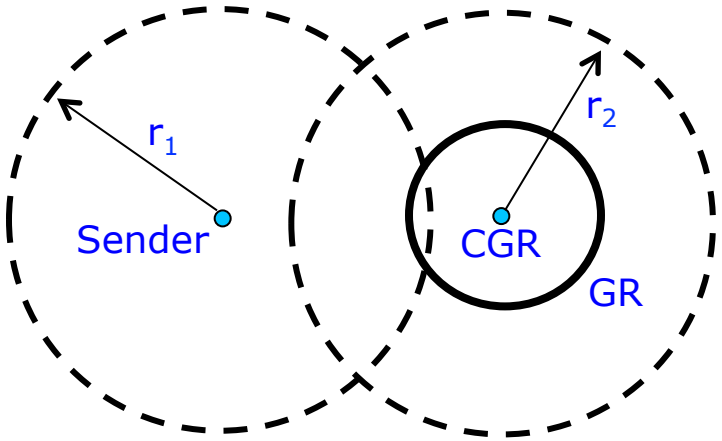


SAGP Animation



SAGP Heuristics

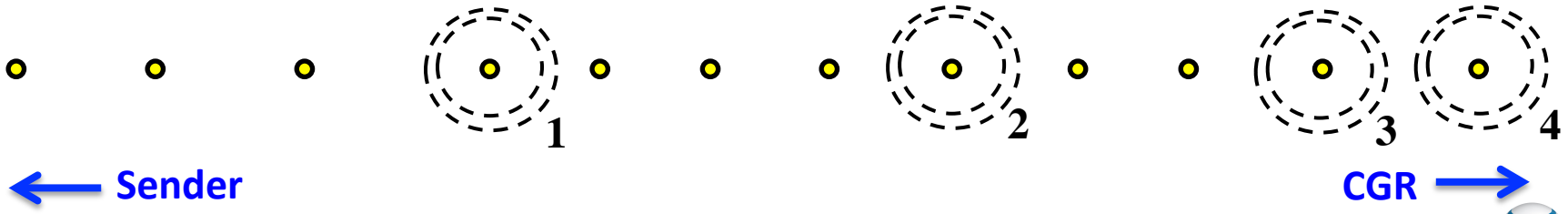
- Retransmit P iff (M or T or CD) and In FZ
- **M:** Heard < M transmissions of P?
- **T:** All transmissions at least T distant?
- **CD:** Am I closer to CGR than all heard?
- Forwarding Zone (**FZ**) = union of two circles



CGR = Center of Geocast Region

SAGP Is Scalable

- **Claim:** when all *n* devices can hear each other, SAGP uses *O*(*lg n*) *transmissions/geocast* average
- **Proof Sketch:**
  - Cost is dominated by CD heuristic
  - Each transmission approximately halves number of devices closer to CGR than transmitter
- This is the most critical special case



The FCOP Algorithm *

- **For a device M to monitor region MR:**
  - Initially set *Recent Response Cache* (RRC) to empty
  - Once per P seconds, geocast query message to MR
  - When device receives a query message Q:
    - Remove msgs from RRC older than P – ε
    - If no msg remains in RRC that was sent to a region containing location L of origin of Q, then
      - Geocast a response message w to targetRegion(L)
      - Record timestamped w in RRC
  - When device receives *any* response message, record info from it in client database for use by application

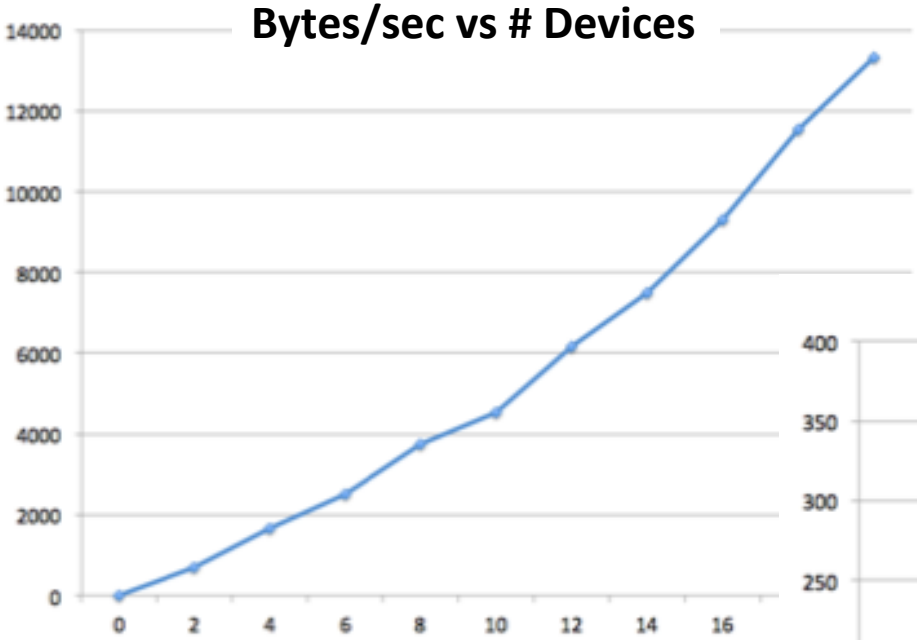
*** See MILCOM 2012 paper for details**

FCOP Algorithm Evaluation

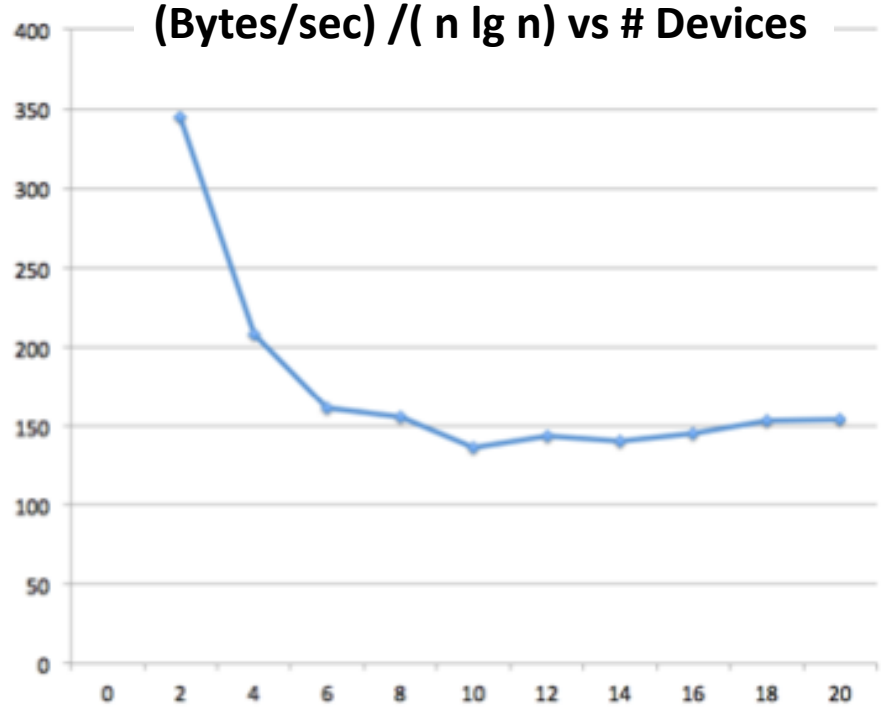
- In dense *COP configuration*, FCOP uses $O(n \lg n)$ bytes per P seconds, because each of n devices sends two geocasts per P sec (1 small query, 1 response)
- Major improvement over $\Omega(n^2)$ of other approaches
- Experimental evaluation: GC1/PSCommander prototype tested for $n = 2 .. 32$ devices in the field
- Measured bytes / sec transmitted over the (common) network
- Implemented using 802.11 (ad hoc WiFi) at 2.4 GHz

COP configuration = each device monitors all other devices

FCOP Experiment Results (Excerpt)

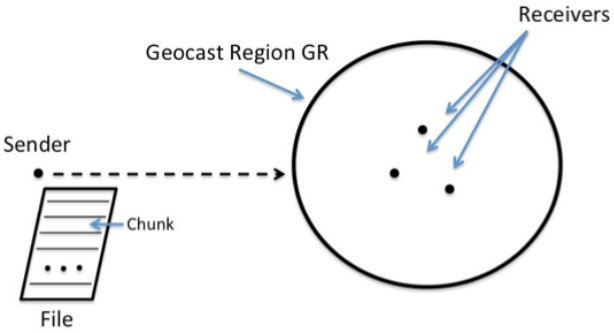


Cost ≈ 154 n lg n →



Geocast File Transfer (GFT) *

- File transfer to all in an area
- Novel protocol key ideas:
  - Geocast all file chunks in order
  - Receivers then request re-sends of missed chunks
  - Sender waits and pools requests
  - Sender geocasts requested chunks in order
- Results:
  - *O(k* lg *n)* bytes transmitted *vs* ~n^2 for traditional
  - *Subconstant* time per byte per recipient



*** See MILCOM 2013 paper for details**

GFT Results

(Excerpt)

Bytes

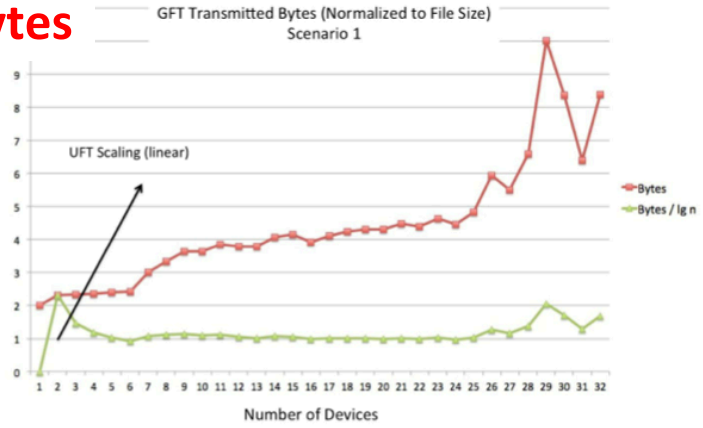


Fig. 7. Scenario 1: GFT Normalized Bytes vs # devices

Transfer Success

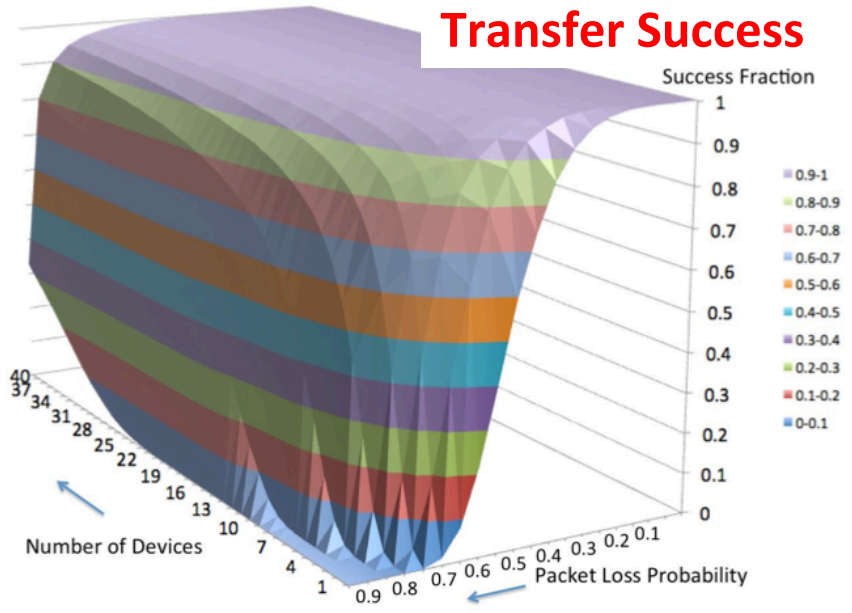


Fig. 12. Scenario 1: GFT Success vs #devices vs packet loss probability

Time (Scenario 1)

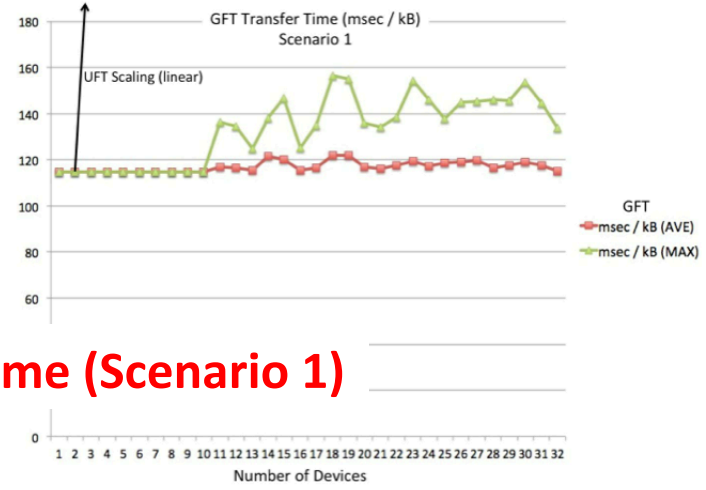


Fig. 10. Scenario 1: GFT Normalized Time vs # devices

Time (Scenario 2)

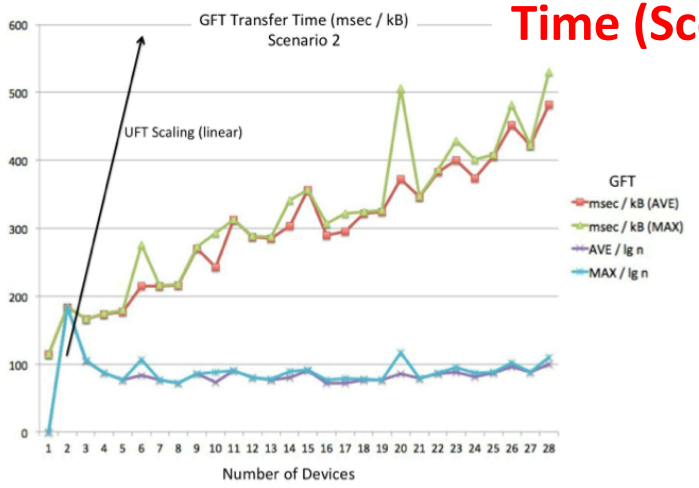


Fig. 11. Scenario 2: GFT Normalized Time vs # devices

Summary

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